A Report for the Director
of the National Science Foundation

The International Decade of Ocean Exploration:

A MID-TERM REVIEW

by the
National
Advisory
Committee on
Oceans and
Atmosphere

August 29, 1975

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* Mr. Wheaton succeeded Thomas A. Clingan who resigned to accept appointment as Deputy Assistant Secretary of State.

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PREFACE

In February 1974, NACOA was asked by the Director of the National Science Foundation to review the International Decade of Ocean Exploration, then approaching its midpoint, and to make recommendations regarding its future.

Strictly speaking, the IDOE is an international effort, carried on under the auspices of the United Nations, to devote the period 1971-1980 to a series of long-term, continuing, cooperative investigations aimed at accelerating progress toward effective utilization of the ocean and its resources. However the U.S. contribution to the IDOE, managed by the National Science Foundation, is a major national program in its own right, and it is this effort that NACOA was asked to review.

In his request, the Director noted that IDOE was approaching its fifth year as an NSF program, and that ". . . this half-way point is an appropriate time to review the status of the IDOE and to consider its future. For example, what should be done about those projects which might be productively extended beyond the nominal 10-year life of the program? Should the IDOE be extended beyond 1980 or should these projects be transferred to other programs?" The Director asked NACOA to "review the scientific, budgetary, and managerial aspects of the program, and more generally, IDOE's compatibility with national priorities in marine and atmospheric sciences." He also identified certain issues and questions as indicative of the scope and flavor desired in this review—these were:

(1) The responsiveness of IDOE to the 1969 guidelines under which it was established.

(2) The current validity of the guidelines as expressions of national and international needs in marine science.

(3) The effectiveness of large, directed research projects in addressing the problems posed by the original guidelines.

(4) Whether IDOE findings to date have been of high scientific quality and have contributed to national and international social, economic, and political objectives.

(5) Given the nominal termination date of 1980, what recommendations would NACOA make about the future of IDOE?

The Director asked that NACOA's evaluation and recommendations be made available to him by the summer of 1975.

NACOA established a panel consisting of Thomas A. Clingan (Chairman), Robert F. Bauer, Charles L. Drake, Thomas A. Fulham, Thomas F. Malone, and Winona B. Vernberg. Upon Dr. Clingan's resignation from NACOA to become Deputy Assistant Secretary of State, Elmer P. Wheaton succeeded him as Chairman. Subsequently Marne A. Dubs was added to the panel.

In conducting its review, the NACOA panel drew upon published and unpublished IDOE reports, briefings by IDOE Office staff and participating scientists, attendance at meetings of various IDOE scientific councils, steering committees, advisory panels, workshops and conferences, and consultation with individuals who have been involved with the IDOE in its early and later stages.

The panel did not attempt to judge firsthand the quality of the scientific accomplishments of IDOE. The entire IDOE program has been subjected to repeated scientific review by NSF advisory panels and by the National Academy of Sciences and the National Academy of Engineering, and the panel felt it could add little in this area. The panel felt it could be most effective by concentrating on the appropriateness of IDOE's goals, the progress being made, the effectiveness of IDOE's approach to managing complex, multidisciplinary, multi-institutional research projects, and the means by which IDOE's accomplishments thus far might provide a basis for identifying future needs and planning ocean research efforts for the years that lie ahead.

I. Summary

The International Decade of Ocean Exploration was conceived in the late 1960's as a means for acquiring the scientific and technical knowledge needed for ocean resource utilization and marine environmental protection on a global scale. The U.S. program for the IDOE, with which this report is concerned, has concentrated its effort in four scientific areas: *environmental quality,* which primarily involves chemical and biological aspects of the marine environment and marine pollution; *environmental forecasting,* which is concerned with oceanic motions and with interactions between the ocean and the atmosphere; *seabed assessment,* which is concerned with the geology and geophysics of the sea floor and the processes of plate tectonics and metallogenesis; and *living resources,* which is concerned with marine ecosystems and the biological productivity of the oceans. The program as a whole has concentrated on studies of the open ocean, as opposed to coastal and estuarine waters, and on problems having global significance as opposed to those of a purely local character.

IDOE projects have typically been long-term, multidisciplinary, multi-institutional endeavors distinctly different in nature from most of the research projects associated with funding agencies such as the National Science Foundation and the Office of Naval Research. In its management of the IDOE, NSF has drawn upon the strengths and capabilities of existing institutions, rather than creating new organizations with their own rigidities. It has encouraged scientists to think in terms of multi-institutional cooperative efforts. It has fostered the growth of international cooperation in oceanic research. It has stimulated marked improvements in data standardization and data exchange, nationally and internationally. And it has provided a vehicle for the initiation and carrying out of research projects which has made possible a number of comprehensive oceanic studies which would have been unlikely had IDOE not existed.

All this has not been accomplished without difficulties. The management philosophy which NSF has adopted, while effective, has been sufficiently different from that to which most scientists are accustomed that a

certain amount of strain and discontent has been generated. Some concern has been reported that the process of initiating and planning new projects has not been sufficiently open to input from all parts of the scientific community. There has been disappointment expressed that the IDOE Office has not provided funds for individual scientists seeking to participate in IDOE projects of other nations. And these has been some feeling that problems of major importance, especially in the area of open ocean biology, have not received the attention they deserve. These criticisms have been voiced directly to the IDOE Office which ameliorated some of the situations described.

These management problems have been a consequence of introducing "big science" into a scientific community accustomed to an atmosphere of "little science," and some strain in achieving mutual accommodation was to be expected and has occurred. Another source of difficulty has been the fact that the level at which the IDOE has been funded (approximately $15 million per year, as compared with estimates that at least $50 to $100 million per year would be required) is not sufficient to permit taking on all the work that needs to be done. Further, NSF strives to avoid duplicating the areas of responsibility of Federal mission agencies.

While we think NSF has done well in managing its IDOE program within the limited resources available, we find it a matter of concern that the resources have remained so constrained that important aspects of the original IDOE concept, such as development of an ocean monitoring system, could never be addressed. Preliminary plans called for a partnership among the Federal agencies, industry, and the scientific community here and abroad, but with the exception of some Federal agency involvement in its initial year, and some joint funding with ONR and NOAA, the IDOE has not evolved beyond an NSF program primarily, involving the U.S. academic science community alone. Although expectations based on the early planning studies were undoubtedly unrealistic, we are not aware of any serious effort to reexamine the pros and cons of pressing beyond existing budget constraints.

On balance, we believe that the IDOE has successfully addressed serious deficiencies in the present understanding of ocean processes and ocean resources, has fostered interinstitutional cooperation among scientists of many disciplines working together in the cooperative efforts required to tackle these deficiencies, and has done much to generate a spirit of international cooperation in this area where little had existed previously. We believe that NSF has been right to allocate the limited funds provided to it primarily to scientific work rather than to applications, and that within its budgetary constraints the IDOE program has been satisfactorily responsive to the original goal of advancing knowledge about ocean resources and ocean uses. We strongly advocate continuing steps to build on the base that IDOE has established.

We make the following specific recommendations:

- Since the program label will increasingly obscure program planning issues, the IDOE, as such, should end as planned in 1980. However the function of supporting long-term, multidisciplinary, multi-institutional ocean studies is an essential one that should be maintained within NSF—perhaps in an Office of Ocean Exploration—and applied to studies of this general sort for which we see a need continuing beyond 1980.
- The funds presently allocated to long-term cooperative ocean studies should continue to be earmarked for such programs, after the decade ends.
- A start should be made now, under NSF leadership, to define goals and guidelines for the programs that should succeed the IDOE. Numerous candidates exist, including some not restricted to ocean phenomena alone. Examples include studies related to the prediction of weather and climate, which depend upon understanding the interactions between the air and the sea, studies of the marine processes responsible for the formation, in past millennia, of ore deposits, some of which lie on land today, and studies of the magnitude and variability of ocean living resource productivity.
- During the remainder of the IDOE, a greater effort should be made to foster the growth of oceanographic competence in developing countries. A distinction should be made between the research interests of the developed nations, which are already characterized by considerable international cooperation, and the research interests—and capabilities—of the less developed coastal nations. Cooperation with the latter is often hampered by their inability to collaborate with or even use the results of research which the more developed countries plan for their coastal waters. Yet their concurrence will be increasingly important. NACOA has long advocated U.S. efforts to involve these nations in ocean research of mutual interest. IDOE, with its orientation toward ocean use and environmental protection, is a logical means toward this end. We would recommend that additional funding be provided to accomplish this purpose.
- Greater emphasis should be placed on assuring full realization of practical as well as scientific benefits inherent in IDOE programs. This will require a more systematic involvement of mission agencies than has heretofore been the case.
- The IDOE Office should seek ways to support individual scientists wishing to participate in IDOE projects of other nations not funded by NSF, should develop means for reporting and publi-

cizing technological developments arising from IDOE projects, and should be flexible in considering whether to fund research proposals which encompass landward aspects of oceanic processes that are the subject of ongoing IDOE studies.

- Every effort should be made to continue to take on new projects during the remainder of the IDOE, and the possibility of jointly funding portions of ongoing projects with appropriate Federal mission agencies should be explored.

II. Background

The International Decade of Ocean Exploration was conceived as a response to the realization that nations would increasingly need to turn to the sea to meet the growing world demand for food, minerals and energy. This realization was accompanied by questions about the extent and distribution of marine resources, their ownership, and the nature and extent of national jurisdiction over the seas, notably in discussions on law of the sea in the United Nations. It was the position of the United States that not enough was known about the nature, location and extent of oceanic resources, the uses to which they could be put, and the technology that would be required to exploit them. To acquire the necessary scientific background quickly and efficiently, the United States proposed the IDOE to the U.N. General Assembly in 1968.[1]

The IDOE concept was endorsed by the Intergovernmental Oceanographic Commission (IOC), an agency of UNESCO, in 1969, and by the General Assembly later that year. Member nations were called upon to formulate proposals for national and international programs, and to make preparations to embark on them as soon as possible so that the Decade might get underway in 1970. Numerous planning studies were undertaken, notably those under the auspices of the IOC by its Group of Experts on Long-Term Scientific Policy and Planning (GELTSPAP)[2] and by the Joint Working Party on the Scientific Aspects of International Ocean Research which produced the "Ponza Report" entitled "Global Ocean Research"[3] and in the U.S., the study conducted jointly by the

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[1] An account of the origins of the IDOE may be found in "The Politics of the Ocean" by E. Wenk, University of Washington Press, 1972. See also "Fisheries and the IDOE" by J. L. McHugh, Proceedings of the Gulf and Caribbean Fisheries Institute, 23rd Annual Session, November 1970, for an account of the goals and aspirations of the IDOE by the first head of NSF's IDOE Office.

[2] Report of the Group of Experts on Long-Term Scientific Policy and Planning, GELTSPAP/I/17, UNESCO/IOC, December 23, 1970.

[3] "Global Ocean Research," a report by the Joint Working Party on the Scientific Aspects of Ocean Research, in "Comprehensive Outline of the Scope of the Long-term and Expanded Program of Oceanic Exploration and Research," UNESCO/IOC Technical series, no. 7, 1970.

National Academy of Sciences and the National Academy of Engineering which produced the report "An Oceanic Quest." [1]

In October 1969, the Vice President of the United States, as Chairman of the National Council of Marine Resources and Engineering Development, formally announced the intention of the United States to contribute to the IDOE, and assigned to the National Science Foundation the responsibility for planning, managing and funding the U.S. program. The Vice President announced a set of goals for the program which centered on

- preservation of the ocean environment by accelerating scientific observations of the natural state of the ocean and its interactions with the coastal margin,
- improvement of environmental forecasting to help reduce hazards to life and property and permit more efficient use of marine resources,
- expansion of seabed assessment activities to premit better management of marine mineral exploration and exploitation,
- development of an ocean monitoring system to facilitate prediction of oceanographic and atmospheric conditions,
- improvement of worldwide data exchange,
- increased opportunities for international sharing of the responsibilities and costs of ocean exploration, to assure better use of limited exploration capabilities.

These goals reflected most of the key recommendations of "An Oceanic Quest." Funds provided for the program, however, have settled at roughly $15 million per year, far short of the $100 million per year envisaged by the Academies. As a consequence many of the early hopes for the IDOE never materialized.

By early 1975, the United States had embarked on 16 IDOE projects, all of which included participation by at least one other nation, with several having as many as 8 or more other countries involved. A total of 36 other nations had participated in U.S. projects. Other countries were slower in starting their own IDOE programs, but by 1975 fourteen projects had been initiated by foreign nations, and scientists from the United States had participated in eight of these, supported by research grants from sources other than the U.S. IDOE program. NSF's IDOE Office has confined its funding to U.S. projects (most of which do involve some foreign participation) developed in accordance with its guidelines and procedures. It is for this U.S. program that NACOA's review was solicited.

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[1] "An Oceanic Quest, the International Decade of Ocean Exploration," National Academy of Sciences and National Academy of Engineering, Washington, D.C., 1969.

III. The U.S. IDOE Program

What's Unique About IDOE

The IDOE program within the National Science Foundation is not the only major international effort in ocean exploration in which the U.S. participates, nor does it represent a major portion of the U.S. effort in oceanography. Other international programs receiving substantial U.S. support include the International Geodynamics Project, the International Phase of Ocean Drilling (IPOD), the Circum Pacific Map Project, and the Global Atmospheric Research Program. Within the United States the IDOE, budgeted at roughly $15 million per year, represents approximately 10-15% of the total Federal effort and approximately 25% of the total NSF effort in ocean research. Comparable or larger sums are allotted to ONR's ocean science program, NOAA's Sea Grant Program, and, in NSF, to the Deep Sea Drilling Project and the oceanographic program within the Division of Environmental Sciences in NSF's Research Directorate.[1]

Many of these programs have as their goals increased understanding and predictive ability pertaining to physical and chemical processes occurring in the oceans, movement of ocean waters, seafloor geological structures and the processes that form them, and the functioning of marine organisms and ecosystems. What then is unique aobut IDOE?

One characteristic is the attempt to develop multinational collaboration. Marine science in the United States started modestly with limited objectives, received a large boost from World War II, and matured further with the International Geophysical Year. The IGY program involved worldwide measurement of geophysical phenomena, including a special effort in the oceans, and set up mechanisms for international

[1] As we go to press, the National Science Foundation is undergoing a major reorganization. One outcome is that the Directorates of Research and of National and International Programs no longer exist, and the research activities in the oceanic, atmospheric and earth sciences which were formerly housed in those two directorates have been brought together under a single Assistant Director for Astronomical, Earth and Ocean Sciences.

cooperation in the collection and exchange of data. This program and the later International Indian Ocean Expedition were international in that information about plans and results was shared, but essentially each country carried out its own program and joint activities were minimal.

During the IDOE a systematic effort has been made to develop truly international projects, and while progress has been slow, a number of examples can be cited, such as MODE-POLYMODE,[1] FAMOUS, and the Nazca Plate study, in which bilateral or multinational participation from planning through execution has occurred.

A second significant characteristic of IDOE is that it represents an instance of governmental initiative in defining a broad area in which scientific knowledge is needed for long-term practical purposes, and in establishing conditions which attract scientific interest and stimulate scientists to take on the burdensome managerial and administrative responsibilities that are required. Chief among these conditions is the setting aside of funds for this purpose. Although the scientific community had, since the late fifties,[2] urged a long-term international effort of a somewhat similar nature, little progress toward that goal had been made through the usual avenues of funding. Certain projects addressing a portion of the need, such as NORPAX, GEOSECS, and the Deep Sea Drilling Project, had some into being by dint of long and patient efforts to obtain funding. IDOE, on the other hand, provided an "umbrella" that greatly accelerated the process, and made it possible to develop and implement a worthwhile new major project in a comparatively short period of time.

A third notable aspect of the IDOE program is that it is specifically designed to fund and manage large projects—projects that involve investigators from more than one institution and sometimes from more than one country—in a way that, by utilizing existing resources and capabilities, diminishes the need for additional capital expenditures and the creation of new permanent institutions. Thus it provides a needed complement to the programs in NSF's Research Directorate [3] which are set up to respond primarily to proposals from individual investigators, or small teams of investigators, working on small-scale projects within a single discipline.

Program Content

Those involved in the early planning were aware that comprehensive assessment of ocean resources, together with related studies of the ocean

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[1] Acronyms are defined in Appendix 1, and brief descriptions of IDOE projects are given in Appendix 2.

[2] See, for example, "Oceanography 1960-1970," National Academy of Sciences Committee on Oceanography, 1959.

[3] See footnote on page 7.

environment, development of required technology, and implementation of ocean monitoring, would be a major task involving considerable expense, and recommendations proffered for the U.S. program were correspondingly grand in scope. Budget levels, however, never exceeded a small fraction of projected needs ($15 million annually as compared with the Academies' estimate on the order of $100 million) and were clearly insufficient for taking on all the projects which the various advisory bodies had identified as desirable. NSF, charged with managing the U.S. program, was faced with the challenge of scaling down the grand vision to something of manageable size and significance while still retaining its essential elements.

What evolved was a primarily *scientific* effort, responsive to the ideas and capabilities of the U.S. oceanographic community, aimed at acquiring the needed *understanding* of the oceans and their resources. Technology development, operational monitoring programs, and efforts applied directly to resource development were omitted. International cooperation and the growth of oceanic competence in the developing nations have played a lesser role than was originally conceived. The essential concept of looking at the ocean in an integrated, coherent, multidisciplinary manner was, however, retained. The projects which IDOE has taken on are of such scope that they would have had considerable difficulty finding funding elesewhere. They are characterized by a management structure in which the participating scientists play a significant role in the design, direction and management of the program. While many of these projects are insufficiently far along to permit more than tentative assessment of success, all indications are that they are scientifically sound and that much useful research is being carried out that would have been unlikely to occur in the absence of the IDOE. While it is too early to tell how great a contribution to improved management and utilization of world oceanic resources the results will make, it is indisputable that knowledge of the oceans and their large-scale processes is growing at a greater rate than would have been achieved by the more traditional approach of "small science".

The IDOE program is organized in four areas as suggested in "An Oceanic Quest": *environmental quality, environmental forecasting, seabed assessment,* and *living resources,* each responsive to one of the goals enumerated by the Vice President in 1969.

- The *Environmental Quality Program* is concerned with the ocean environment. Areas of study include the establishment of baseline conditions for pollution in the marine environment, studies of the rates and mechanisms by which pollutants are added to the oceans and transferred from one part of the ocean system to another, studies of the effects of pollution on marine organisms and ecosystems, and global studies of the chemical constituents

of the oceans at all depths as a key to understanding ocean circulations and mixing processes. Projects in this program thus far have been: Baseline Studies, carried out in 1971-1972; Geochemical Ocean Sections Study (GEOSECS), begun in 1971; Transfer Processes, begun in 1972; and Biological Effects (including the Controlled Ecosystems Pollution Experiment, CEPEX), initiated in 1973. A description of each of these projects is given in Appendix 2.

- The *Environmental Forecasting Program* aims at developing improved physical and mathematical models of the oceans and atmosphere, with emphasis on the interactions between the two and between the upper and lower regions of the ocean. Studies under way are the Mid-Ocean Dynamics Experiment (MODE), begun in 1971, and its successor POLYMODE, begun in 1973, which are concerned with mesoscale eddies in the deep ocean; the North Pacific Experiment (NORPAX), taken on as an IDOE project in 1972 and concerned with ocean-atmosphere coupling over the North Pacific and its impact on the weather and climate of North and South America; Climate: Long-range Investigations, Mapping and Prediction (CLIMAP), begun in 1971 and concerned with reconstruction of past climates from oceanic data; International Southern Ocean Studies (ISOS), begun in 1974 and concerned with the dynamics of the Southern Ocean. MODE, POLYMODE and NORPAX are funded jointly with the Office of Naval Research.
- The *Seabed Assessment Program* is directed toward providing information which will lead to better management of seabed resource exploration and exploitation. It features surveys of the less known continental margins and studies of geological processes along the continental margins and mid-ocean ridges and in the deep ocean basins. Projects included in this program are: South Atlantic Margins, begun in 1971 to study the continental margins of western Africa and eastern South America; Metallogenesis and Plate Tectonics, begun in 1971 and centering on studies of the Mid-Atlantic Ridge (including the French-American Mid-Ocean Undersea Study, FAMOUS) and the Nazca Plate in the eastern South Pacific; Manganese Nodules, begun in 1972 and concerned with the global distribution of this resource.
- The *Living Resources Program* is aimed at understanding the processes affecting the abundance of marine life. It is the newest of the IDOE programs, having begun in 1972, and contains two projects—Coastal Upwelling Ecosystems Analysis (CUEA), which started in 1972 and is concerned with physical and biological aspects of regions of coastal upwelling, and the Seagrass Eco-

system Study (SES), begun in 1974 to study the life cycle of seagrasses, their role in coastal ecology, and their contribution to ocean productivity.

In addition to the research projects in these four program areas, the IDOE Office supports the rapid archiving and dissemination of IDOE data by NOAA's Environmental Data Service, sponsors international workshops to lay the groundwork for future international studies, supports information dissemination through publications and films, and supports training in modern oceanographic techniques for scientists from developing nations.

In recognition of the importance of facilitating practical applications of its research effort, and in order to identify areas of research which may be called upon to complement the studies now under way, the IDOE Office is sponsoring a series of workshops, keyed to the four IDOE program areas, to discuss unfilled needs and potential uses of research results.

Program Management

Guidelines for IDOE proposals require, in addition to the usual NSF standards of sound scientific quality and nonduplication of effort, that the project fit into one of the four IDOE program areas, that the research be primarily oriented toward the open ocean, rather than coastal or estuarine waters, that it not lie within the area of responsibility of a Federal mission agency, and that its long-term nature, or the degree of interdisciplinary or interinstitutional cooperation called for, make it unsuitable for funding through other channels.

IDOE projects have, for the most part, been confined to ocean areas, to the frustration of scientists concerned with subjects such as metallogenesis and climate which, while dependent on oceanic processes, are not confined geographically to the ocean themselves. To understand the process of ore formation it is desirable to study the geology, the earthquakes, the volcanism, and the ore deposits on land above the subduction zones, as well as the processes along the mid-ocean ridges. But IDOE funding stops at the beach. Similarly, stratigraphic and paleontological evidence of past climates can be found on land as well as at sea, yet IDOE supports only studies of marine data.

Meshing with an ongoing project often presents problems. Individual investigators must give up some of their independence and subordinate their interests to the goals of the project as a whole. Many scientists, though recognizing its necessity, find this difficult, and may choose not to participate at all or do so uncomfortably with feelings of stress.

IDOE normally does not fund individual small studies of the sort that NSF's Research Directorate has traditionally supported.[1] During its

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[1] See footnote on page 7.

first five years, the IDOE Office received some 778 proposals, and funded 422, or about 54 percent, at an average of $160,000. (Each such grant may be one of five or six making up a single project whose total funding is on the order of $1 million.) By way of comparison, the Oceanography Section of the Division of Environmental Sciences in NSF's Research Directorate considered in a typical year (fiscal 1974) 460 unsolicited proposals, and funded 282 (61 percent) in amounts averaging about $48,300. During the first year or two, there was some confusion reported between NSF's IDOE Office and the scientific community as to IDOE's purpose and substance. As a consequence a number of the early proposals were not funded because they were inappropriate to the kind of program that was slowly taking shape. With the passage of time the process has become smoother and more efficient, and communication between IDOE program managers and the scientific community has improved. Recent proposal turndowns have been primarily either for poor scientific quality, insufficient funds for potentially good projects (the Indian Ocean leg of GEOSECS, for example), or because the guidelines would be stretched too far to justify support (the land aspects of metallogenesis).

Although IDOE initially took on several projects which were already underway or in an advanced stage of planning,[1] for the most part the process of identifying potential topics for IDOE support and laying the initial groundwork for project development has been accomplished through workshops and planning grants. The philosophy and practice are described in Appendix 2; the result has been that to a large extent, ideas emanate from and are developed by the scientists themselves, with guidance from NSF. While this has undoubtedly done much to keep the program attuned to current ideas and capabilities within the scientific community, one consequence has been that scientists who participate in the initial workshop and planning grant that develops a new project appear to be at an advantage when it comes to submitting proposals to participate in that project. This, combined with the nearly level funding of the IDOE program and the long-term nature of most IDOE projects, has made it difficult for scientists not already in the program to break in.

To manage IDOE projects, a practice (which is described in Appendix 2) has been developed in which much of the management function is carried out by the participating scientists themselves, rather than by government officials. This has avoided problems arising from management insensitivity to conditions conducive to good science. However it has imposed a substantial demand on the scientists' time for unavoidable

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[1] NORPAX and CUEA were adapted from ongoing studies; GEOSECS, CLIMAP, MODE, South Atlantic Margins and Nazca Plate were in advanced stages of planning.

administrative tasks, which may have the effect of deterring some capable scientists from participating in IDOE programs.

A final point that has been raised by those whose interests lie in the international arena is that the original hopes for a truly international program have not been realized. They charge that too many IDOE projects appear to be essentially U.S. projects with some foreign collaboration, rather than being truly international. (Bilateral efforts, like the French-American FAMOUS and the Russian-American POLYMODE, are exceptions.) Further, the IDOE Office does not support individual scientists wishing to participate in IDOE projects of other nations.

Accomplishments

The IDOE program thus far has produced findings of scientific significance, findings having direct significance for ocean resource development and utilization, data collections that will prove valuable in many present and future studies, and technical and managerial methods of approach which will have considerable impact on the practice of oceanography.

Examples of specific scientific results include the measuring and mapping, in MODE, of a mesoscale ocean eddy for a significant portion of its lifetime, and the construction in CLIMAP of a map of sea surface temperature during the last ice age 18,000 years ago. Results affecting ocean utilization include the gathering of comprehensive geophysical and geological data on the continental margins of the South Atlantic, and the preparation of a series of maps showing the world wide distribution of manganese nodules and their metallic content, with emphasis on the regions of greatest concentration in the North Pacific. Data sets providing a needed base for future studies include the compilation of background levels of pollutant concentrations in many portions of the world ocean, with emphasis on U.S. coastal waters, and the collection and analysis of seawater samples from all depths to determine the chemical constituents of the global ocean in GEOSECS. Technical methods of approach include a substantial effort in data standardization and data exchange which has, for the first time, made data collected in different regions truly intercomparable (GEOSECS and NORPAX are prime examples), and fostering the use of industrial multi-channel seismic reflection systems, which have not previously beeen available to academic institutions, in the continental margin studies.

In addition, the IDOE has created an environment in which scientists have come to think in terms of multidisciplinary, multi-institutional endeavors far more readily than has been the general rule. An atmosphere has been established that is conducive to the cooperative studies that will be increasingly needed as we integrate small bits of knowledge into a comprehensive understanding of the nature and

dynamics of our total global environment. One example is the coastal upwelling work and the opportunity it has provided for physical and biological oceanographers to work together.

The IDOE has also had a substantial influence on international cooperation in oceanic research. What started out as an essentially unilateral effort with international aspirations now shows many examples of international collaboration. The growth of MODE, a U.S. program with some British participation, into POLYMODE, a joint effort of the United States and the U.S.S.R., is one example. FAMOUS, which utilized one American and two French submersibles in a joint study of the active central rift of the Mid-Atlantic Ridge, is another. A third is the series of international workshops which have involved scientists and economists from many countries in such areas as the geology of the Caribbean; metallogenesis, hydrocarbons and tectonic patterns in Southeast Asia; and the *El Nino* phenomenon along the western coast of South America. A fourth is the degree of coordination that has existed between IDOE's Seabed Assessment program and the International Geodynamics Project. While considerably more international participation is desirable, the IDOE program has already generated much that did not previously exist.

Program Emphasis

Thus far, the Environmental Quality and Environmental Forecasting programs have had the greatest emphasis, receiving the largest share of the funds.

Because there are insufficient specific economic incentives or scientific resources in industry to permit the large investments required to provide the scientific basis for improved environmental forecasting, it falls to government to support research on this problem. This same assessment applies to the need for scientific data in the development of policies and programs designed to preserve and protect the marine environment, particularly the deep ocean.

In addition, the IDOE staff found that the problems involved in environmental quality and environmental forecasting were scientifically and technologically ready to benefit from infusions of large amounts of money. There has been a recognized scientific leadership concerned with the design and logical progression of the large-scale field experiments that are needed to improve the scientific understanding of our environment.

While the same reasoning applies to studies of metallogenesis, a different situation exists with respect to petroleum and minerals from the sea. Here there are private interests with powerful economic incentives to seek these resources on their own initiative. Moreover, we have some pretty good ideas about where reserves exist to meet our immediate needs. The problems are the persistent ones—international politics, economics,

and technology. Thus, the seabed assessment work, as it is now conceived, can approach its tasks of exploration and basic research in a less urgent manner than that called for in environmental quality and environmental forecasting.

Living resources have not been studied as intensively as some of the other areas taken up by IDOE. Initially there was a desire not to overlap fisheries research interests, but open ocean biology is not covered by any agency, and this is an area we cannot continue to neglect if we are to gain an understanding of the complex interrelationships involved in ocean productivity.

There is one additional area in which we feel more emphasis is needed, and that concerns the new technology developed in the course of IDOE projects. It is important that information about new techniques and instruments be made openly available to others. This presents a problem because of the dearth of suitable journals for publishing such details, but we urge the IDOE Office to make an effort to see that the techniques and technology that have been developed are duly publicized. This is but one of a wide range of problems concerning ocean technology, and it may be that the Institute for Engineering Research in the Oceans which NACOA has recommended previously [1] would be a suitable vehicle toward solution.

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[1] "Engineering in the Ocean," a report for the Secretary of Commerce by the National Advisory Committee on Oceans and Atmosphere, November 15, 1974.

IV. Assessment

In requesting NACOA to undertake this review, the Director of the National Science Foundation raised five specific questions (see Appendix 3). Our answers to these questions follow.

Has the IDOE program been responsive to the 1969 guidelines under which it was established?

To the extent that an explicit set of initial guidelines existed, they may be found in the six goals enunciated by the Vice President in October 1969, and reproduced here in Appendix 2.

The first of these goals, directed toward assessing and predicting man-induced and natural modifications in the oceans, identifying damaging effects of waste disposal at sea, and comprehending the interaction of various levels of marine life in order to prevent depletion or extinction of valuable species as a result of man's activities, has been addressed by IDOE's Environmental Quality and Living Resources programs.

The second goal, calling for improved physical and mathematical models of the ocean and atmosphere to yield accurate, timely, and geographically precise environmental forecasts, has been addressed by the Environmental Forecasting program.

The third goal, concerned with the acquisition of needed knowledge of seabed topography, structure, physical and dynamic properties, and resource potential, has been addressed by the Seabed Assessment program.

The fourth goal listed by the Vice President, concerning the design and deployment of an ocean monitoring system, has not been directly addressed by NSF's IDOE program. Ocean monitoring systems are extremely expensive, and NSF could not have taken on this task effectively with the resources available. Ocean monitoring has again attracted attention within the past year in the context of the need to acquire global ocean data to assess the likelihood of climatic change and to assist in the development of climatic models, and it is possible that as part of a national climate program, or in conjunction with the Global Atmospheric Research Program, the job of designing and implementing an ocean monitoring system will be incorporated as part of a new Federal

effort. In restrospect it is regrettable that IDOE was not provided the means to make a start.

The fifth goal, concerning modernizing and standardizing marine data systems, has been taken on by the National Oceanic and Atmospheric Administration's Environmental Data Service, with funding from IDOE. Standards for data reporting, inventorying, and archiving are set for all IDOE projects, and a data exchange procedure has been developed which appears to be working effectively, both nationally and internationally.

The sixth goal, pertaining to increased opportunities for international sharing of the responsibilities and costs of ocean exploration, has been addressed, if only partially, by the entire U.S. IDOE program.

Progress has been made, under the IDOE banner, in five of these six areas. Undoubtedly there is more that could and, we hope, will be done, but we feel that, considering the financial resources available, NSF has done an excellent job of promoting research activities which directly addressed these goals, activities which would have been unlikely to occur in the absence of IDOE, and which in many instances have already produced results which will be of value in moving toward these goals. At the same time, NSF's IDOE program has stimulated international cooperation in ocean research.

NSF was charged with a monumental task and given very limited resources with which to accomplish it. We believe that in general the allocation of these resources was done wisely, and that, within its budgetary constraints, the IDOE program has been satisfactorily responsive to the original guidelines. However, had more funds been available, the goal concerning ocean monitoring could have been addressed, and more progress could have been made toward developing the international competence needed to permit sharing with other nations the responsibility of ocean exploration. We are not aware of any serious effort to evaluate the significance of these deficiencies and to estimate the costs and activities needed to address them effectively. This should be done as a basis for determining feasibility and desirability.

Are those guidelines currently valid as expressions of national and international needs in marine science?

They are. Events that have transpired since the guidelines were formulated have generally served to reinforce their validity. The oil crisis and the resulting realization, within the United States, of the need to assess and exploit our offshore oil and mineral resources; droughts and wheat crop failures which have made us increasingly aware of the susceptibility of terrestrial food production to changes in climate which are all too likely and too poorly understood; fishery failures which have brought home to us that we cannot sit back and assume that the fish will be there when the wheat isn't—all have served to give even more

emphasis to the crucial role the oceans play in our survival on earth, and to confirm that the IDOE was a timely and needed effort.

One significant development that may call for greater emphasis on those guidelines concerned with international cooperation is the growing prospect of extended jurisdiction of coastal nations over their offshore waters. This increases the likelihood that the approval and cooperation of coastal nations will become essential for research within those waters, and suggests that more emphasis be placed on those aspects of the IDOE program most likely to generate response among other coastal nations.

Have large, directed research projects been effective in addressing the problems posed by the original guidelines?

We feel they have, as far as the scientific problems go. The IDOE Office has attempted to ensure that projects have not only been major efforts involving large numbers of investigators, but that they have been comprehensive in scope with components so integrated as to produce a synergistic effect. This latter aspect is difficult to assess, but those projects which have already completed one or more well-defined phases (e.g. MODE, the Atlantic and Pacific legs of GEOSECS, etc.) have demonstrated the effectiveness of this approach in producing results that would have been unlikely otherwise. More to the point, however, is that numerous small research projects were already under way, supported by NSF and others, in all of these areas. Additional funds could have been made available for more of the same, and this would certainly have been useful. What the IDOE projects have accomplished has been useful in a somewhat different way that is particularly welcome—they have addressed aspects of these problems that could not, generally speaking, have been addressed by conventional small projects. In so doing, not only have they produced useful scientific results, they have also pointed out a new and effective way of taking on big problems, and they have encouraged a willingness to participate in cooperative efforts that will, we believe, be increasingly needed in the future.

Have IDOE findings to date been of high scientific quality, and have these contributed to national and international social, economic, and political objectives?

NACOA has not attempted to assess first hand the scientific quality of the IDOE program. We believe there has been adequate review of this aspect by NSF's IDOE Advisory Panel and periodically by the National Academy of Sciences and the National Academy of Engineering. What results are available appear to be scientifically sound, and work in progress appears promising.

Several contributions of a non-scientific nature are worthy of mention. The international cooperation generated by the program represents

progress toward a significant foreign policy objective. The amassing of baseline data on pollutants in the ocean, which will be of use to regulatory agencies in setting pollution standards and devising monitoring programs, is a major technical contribution, basic to the setting of environmental policy. The publication of a series of maps showing the world-wide distribution and metal content of manganese nodules is a contribution to economic goals.

We believe more could and should be done to enhance the prospect of increased public benefit from IDOE activities. We are aware of the series of NSF marine science affairs workshops whose aim is to consider potential applications, identify those additional areas of expertise which should become involved in implementing results, and lead to plans for incorporating those disciplines into the ongoing programs. We hope these workshops will recommend specific steps to close existing gaps between IDOE findings and applications. In particular, the links between individual projects and the long-range goals set at the beginning, and the prospect of involving mission agencies in the effort to develop applications should be kept in mind.

Given the nominal termination date of 1980, what does NACOA recommend about the future of the IDOE?

The International Decade of Ocean Exploration is doing a good job. We believe the "Decade" should end in 1980, as scheduled, not because all oceanic problems will have been solved, or because it would not be productive to continue the program, but because its stated purpose—a decade of concentrated effort to make a start toward acquiring the needed understanding of the oceans—will have been accomplished.

This does not mean that the work IDOE does should terminate. In fact its institutionalization would be desirable, and in the following section we specify how this might be accomplished.

V. Recommendations

We are persuaded of the importance of continuing to expand our knowledge and understanding of the oceans and associated atmospheric phenomena, not only for the sake of science and to improve our utilization of ocean resources, but because the oceans represent a major portion of our global environment with potential impact on many facets of human life, from survival to amenities—impacts about which too little is known. There is no dearth of problems calling for study; in fact we see so many that we are reluctant to identify some as more pressing than others. For example, we see a growing need for integrated studies of the oceans and atmosphere which would further extend the work of projects such as NORPAX, CLIMAP, and ISOS. We also see a need for comprehensive studies of the global biological productivity of the oceans, in much the same vein as the global study of oceanic chemical constituents which has been undertaken in GEOSECS. The question is not so much what to study as how best to use our present capabilities and institutions to meet the needs of the future. To this end we make the following recommendations:

- *The function of providing support for long-term multi-institutional, multidisciplinary studies of the oceans is an essential one that should be kept intact.* In the IDOE, the National Science Foundation has acquired skill, experience, and expertise in the initiation and management of such studies, drawing upon the strengths of existing organizations and avoiding the need to create new institutions with their own rigidities. When the decade program ends, as we feel it should, this capabiilty should not disappear, but through some means, perhaps an Office of Ocean Explorations within NSF, should be established on a continuing basis.
- *The funds presently allocated to long-term cooperative ocean studies should not be lost when the decade ends.* The present budget has made possible a viable program whose value, despite its limitations, is sufficient to justify its continuation and possible

expansion. If anything, the program has been handicapped by its virtually level funding. It is important that when the decade ends, these funds continue to be earmarked for long-term, multidisciplinary, cooperative ocean studies.

- *NSF and the scientific community should start getting organized now for the work that is to follow when the decade ends.* The process of identifying goals and guidelines for a future effort in comprehensive studies of the ocean should develop from a broad base, not only in ocean science, but also in other disciplines which can contribute considerations of practical productivity and usefulness. These include economics, law, political science, medicine, and engineering, among others.

We suggest that the program which emerges when the decade ends not be as strictly limited to the oceans themselves as is the IDOE, so that oceanic processes can be studied in the most appropriate manner, even when that includes work conducted on land. We hope that topics such as climate, which—while not entirely oceanic in nature—are significantly affected by the oceans, will be included. Studies of seabed resources and metallogenesis should find ways to bridge the gap between continents and oceans. Parts of the earth which were under the sea millennia ago when minerals began to form are on land today, and geologists and geophysicists studying these processes should not be arbitrarily constrained to stop at today's shoreline. This may require a program specifically designed to bring terrestrial and marine geophysicists together, just as the IDOE has brought together physical, chemical, and biological oceanographers.

In addition, of course, these ocean-related studies will benefit from coordination with other ongoing programs on related subjects. Studies of seabed resources should continue to be coordinated with the International Geodynamics Project; studies of ocean pollution might be more closely integrated with international efforts in environmental preservation such as the UN Environment Program; studies of oceanic circulations and their interaction with the atmosphere might be jointly planned with the Global Atmospheric Research Program, which is already planning for a possible Climate Dynamics Decade in the 1980's.

While we see a continuing need for programs supporting long-term, multidisciplinary, cooperative studies, we do not believe it is necessary for all international cooperative efforts to be expensive multidisciplinary programs, especially since many of the smaller nations cannot easily afford to participate in such ambitious projects. The fact that IDOE has incorporated both of these aspects—bigness and internationalism—does not mean that they must or should remain tied together. There is a need for international cooperation in studying problems of global scope, such as those involving the oceans. Such problems can be attacked by large or

small programs as the questions being asked may require. There is a separate and distinct need for support of big multidisciplinary approaches to complex problems—whether they be national or international.

For the remainder of the decade we recommend that:

- *There should be a concerted effort to encourage greater international cooperation in ocean research, with special emphasis on fostering the growth of oceanographic competence in the developing coastal nations.* There is a distinct possibility that in the future, ocean research will be much more subject to the control of coastal nations than it has been in the past. Many of these nations are less developed technologically than the United States, and many find difficulty in contributing to such research or in using its results. Until they have their own oceanographic expertise, these governments may be disinclined to agree to proposals for oceanic research in waters under their jurisdiction.

  It is clearly in our own interest to foster a willingness on the part of coastal nations to support and cooperate in marine-related studies. In fact, this will be essential for full development of the global ocean monitoring system that was one of the original IDOE goals, and that seems increasingly necessary if we are to understand global ocean interactions, establish a basis for international pollution control, and make headway in understanding and predicting climatic change. We made this point, in the broader context of Law of the Sea negotiations, in our First Annual Report three years ago. It deserves both reiteration and emphasis.

  This recommendation is still valid. To implement it will cost money. The development of international competence and cooperation should not be at the expense of ongoing studies. NSF, in cooperation with other Federal agencies having similar goals, should take steps to identify suitable means for accomplishing this end, assess costs, and seek whatever additional funds are required.

- *There should be increased emphasis on assuring realization of the practical implications of ongoing and planned IDOE research.* The IDOE Office is presently considering ways to incorporate into its program studies of the potential practical benefits of its oceanic research. While plans are not yet sufficiently formulated for us to comment on them, we commend this intent. We particularly urge that the mission agencies, and those industries which represent potential users, be brought into the process.

- *The IDOE Office should seek ways to support individual scientists wishing to participate in IDOE projects of other nations,*

should make an effort to develop suitable vehicles for reporting and publicizing technology developed in IDOE projects, and should be more flexible in considering research proposals which include landward aspects of the oceanic processes being studied in ongoing IDOE projects. Such actions would do much to enhance and complement ongoing IDOE research, and would represent steps toward implementing the recommendations outlined above.

- *New projects should continue to be taken on as the Decade progresses.* As long as the IDOE remains level funded, new projects can be taken on only to the extent that ongoing projects are completed or scaled down. We recognize the difficulties, but we urge the IDOE Office to make every effort to continue to be open to new initiatives arising within the scientific community.

It should be possible for NSF to take advantage of growing interest in some ongoing projects on the part of other Federal agencies. These are changing times, marked by increased awareness of world dependence on fisheries for food, on offshore oil and gas for energy, and on marine minerals for industry, by the growing realization that coastal and near-shore areas are threatened by industrial and municipal wastes, and especially by the increased likelihood of world-wide acceptance of a 200-mile extended resource zone under coastal nation jurisdiction. In this setting, mission agencies such as ERDA and EPA may well find themselves becoming interested in aspects of marine research that did not previously concern them. As the situation changes, and particular projects appear to be relevant to the expanded missions of these agencies, the possibilities of joint sponsorship should be mutually explored.

Appendix 1. Acronyms

CEPEX	Controlled Ecosystems Pollution Experiment
CLIMAP	Climate: Long-range Investigations, Mapping and Prediction
CUEA	Coastal Upwelling Ecosystems Analysis
FAMOUS	French American Mid-Ocean Undersea Study
GELTSPAP	Group of Experts on Long-Term Scientific Policy and Planning
GEOSECS	Geochemical Ocean Sections Study
IDOE	International Decade of Ocean Exploration
IGY	International Geophysical Year
IOC	Intergovernmental Oceanographic Commission
IPOD	International Phase of Ocean Drilling
ISOS	International Southern Ocean Studies
JOIDES	Joint Oceanographic Institutions for Deep Earth Sampling
JOINT	(not an acronym) A series of joint physical and biological field studies conducted as part of CUEA
MODE	Mid-Ocean Dynamics Experiment
NACOA	National Advisory Committee on Oceans and Atmosphere
NOAA	National Oceanic and Atmospheric Administration
NORPAX	North Pacific Experiment
NSF	National Science Foundation
ONR	Office of Naval Research
POLYMODE	A joint U.S.-U.S.S.R. project, successor to a Russian program called POLYGON and the U.S. IDOE project MODE
SES	Seagrass Ecosystem Study

Appendix 2. Description of the U.S. IDOE Program

Origins

The U.S. IDOE program owes much of its present shape and form to the planning study conducted jointly by the National Academy of Sciences and the National Academy of Engineering which produced the report "An Oceanic Quest," [1] in which the IDOE was characterized by ". . . *long-term* and *continuing* investigations of *cooperative* nature, directed toward *objectives of widespread interest* concerned with more effective *utilization* of the ocean and its resources." A number of specific recommendations were made, including: organization of the U.S. effort in four major program areas (geology and nonliving resources, biology and living resources, physics and environmental prediction, geochemistry and environmental change); inclusion in the overall effort of programs in the development of new technology, establishment of new program management procedures, and encouragement of associated social studies; the importance of strengthening the possibilities and the apparatus for international cooperation. The Academies' report estimated the funding level required as on the order of $100 million or more per year, averaged over the Decade—a level which was never even approached in actuality.

In October 1969 the Vice President of the United States, acting in his capacity as chairman of the National Council on Marine Resources and Engineering Development, and speaking for the President, formally announced the intention of the United States to participate in the International Decade of Ocean Exploration, and assigned to the National Science Foundation the responsibility for planning, managing and funding the U.S. program. The Vice President set forth the following goals for the program:

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[1] "An Oceanic Quest, the International Decade of Ocean Exploration," National Academy of Sciences and National Academy of Engineering, Washington, D.C., 1969.

1. Preserve the ocean environment by accelerating scientific observations of the natural state of the ocean and its interactions with the coastal margin—to provide a basis for (a) assessing and predicting man-induced and natural modifications of the character of the oceans; (b) identifying damaging or irreversible effects of waste disposal at sea; and (c) comprehending the interaction of various levels of marine life to permit steps to prevent depletion or extinction of valuable species as a result of man's activities;
2. Improve environmental forecasting to help reduce hazards to life and property and permit more efficient use of marine resources—by improving physical and mathematical models of the ocean and atmosphere which will provide the basis for increased accuracy, timeliness, and geographic precision of environmental forecasts;
3. Expand seabed assessment activities to permit better management—domestically and internationally—of marine mineral exploration and exploitation by acquiring needed knowledge of seabed topography, structure, physical and dynamic properties, and resource potential, and to assist industry in planning more detailed investigations;
4. Develop an ocean monitoring system to facilitate prediction of oceanographic and atmospheric conditions—through design and deployment of oceanographic data buoys and other remote-sensing platforms;
5. Improve worldwide data exchange through modernizing and standardizing national and international marine data collection, processing, and distribution; and
6. Accelerate Decade planning to increase opportunities for international sharing of responsibilities and costs for ocean exploration, and to assure better use of limited exploration capabilities.

Project Descriptions

The NSF program, following the lines suggested in "An Oceanic Quest," is organized in four program areas: Environmental quality, environmental forecasting, seabed assessment, and living resources, each responsive to one of the goals enumerated by the Vice President.

Table 1 lists all past and current U.S. IDOE projects in each of these programs, their starting dates, expected duration, number of scientists participating, expected total cost, and other Federal agencies involved. There is a range of possibilities for interagency cooperation, from nearly equal sharing of the total funding, as in the case of MODE and NORPAX which are funded jointly by IDOE and ONR, to minimal involvement in some aspect of data collection, such as the use of NOAA data buoys (funded by ONR and IDOE) in NORPAX and ISOS. Joint

Table 1. Major U.S. IDOE Projects

Project	Number of Institutions	Number of Scientific Investigators	Year Initiated	Expected Year of Completion	Estimated Total Cost (in Millions of Dollars)	Other U.S. Agencies Providing Funds [1]
Environmental Forecasting						
NORPAX	16	37	1971	1981	30.0	ONR
CLIMAP	5	18	1971	1979	7.0	
MODE	16	45	1971	1974	8.0	ONR, NOAA
ISOS	7	13	1974	1980	6.0	NSF
POLYMODE	10	30	1975	1979	10.0	ONR, NOAA
Environmental Quality						
GEOSECS	14	28	1971	1978	18.5	
POLLUTANT BASELINES	17	30	1971	1972	2.3	
POLLUTANT TRANSFER	9	10	1972	1980	10.0	
BIOLOGICAL EFFECTS						
FIELD (CEPEX)	5	10	1973	1979	8.0	
LABORATORY	6	8	1973	1981	10.0	
Seabed Assessment						
SOUTH ATLANTIC MARGINS	2	15	1971	1975	4.0	
NAZCA PLATE	3	40	1971	1977	6.0	
MID-ATLANTIC RIDGE	4	8	1972	1975	1.0	NSF,ONR,NOAA
MANGANESE NODULES	10	18	1972	1978	4.0	
Living Resources						
CUEA	13	24	1972	1979	15.2	
SES	10	11	1974	1981	7.0	

[1] U.S. Agencies participating other than NSF's IDOE Office:
NOAA — National Oceanic and Atmospheric Administration
ONR — Office of Naval Research
NSF — Deep Sea Drilling Project; Division of Environmental Sciences; Office of Polar Programs

funding makes possible certain very expensive programs like POLYMODE, whose budget, estimated to exceed $4 million per year, would put quite a strain on the resources of any one agency. Interagency funding is not without its problems, however, as the uncertainties associated with changes in the budgets and priorities of several agencies must now be taken into account.

The **Environmental Quality Program** is responsive to the goal concerning preservation of the ocean environment. The component projects in this program, and their contributions to this goal, are:

Pollutant Baselines

This project was carried out during 1971-72. At that time reports from several groups of experts on marine pollution had pointed out the paucity and unreliability of existing data on pollutants in the marine environment. The baseline studies took a major step toward solving this problem by undertaking a coordinated analysis of concentrations of major pollutants in inshore and open ocean areas of the Atlantic and Pacific Oceans, the Gulf of Mexico and the Caribbean Sea.

Measurements were made of concentrations of potentially toxic substances, mostly in organisms, but also in water and sediments. These have served to establish normal background levels which have proved useful in subsequent baseline studies (such as those carried out in connection with oil and gas development on the Outer Continental Shelf), and also to give some indication of the changes in these concentrations attributable to human activities. Considerable emphasis was placed on intercalibration and data standardization. This study is now the major reference for oceanic pollution levels.

Geochemical Ocean Sections Study (GEOSECS)

GEOSECS, which began in 1971, is designed to provide measurements of the spatial distribution of those chemical constituents of ocean water that will contribute to a better understanding of stirring and mixing in the deep ocean and the exchange of energy and material between the atmosphere, the surface layers of the ocean, and the deep ocean waters. It also serves as a geochemical baseline survey of the world ocean.

During the field phase of the project, a large number of seawater samples were collected at various depths from the surface to the bottom, along sections of the Atlantic and Pacific Oceans from the Arctic to the Antarctic. These samples are being analyzed for a number of chemical constituents, including radioisotopes introduced into the oceans as fallout.

Data quality has been controlled by continuous intercalibration and standardization exercises. While GEOSECS measured things that have been measured before, it did so with more consistent sampling and analytic techniques at all stations, and more complete geographic coverage, than previous studies. The data collected are being used to construct more accurate and more detailed models of ocean circulation and mixing than were previously available.

Transfer Processes

This project, initiated in 1972, is an integrated research effort into the rates and mechanisms by which pollutants are added to the oceans, and the mechanisms by which pollutants are transferred from one part of the ocean system to another (for example from seawater to marine organisms, and vice versa). It includes an evaluation of human impact on the environment, and a substantial effort to collect the data needed to suggest corrective action.

Measurements have been made of rates of addition of the most significant classes of pollutants from all the major sources, and the influence of these additions on open ocean systems. The program is adding to our comprehension of how pollutants move about in the environment, and is unique in that it covers all classes of pollutants and all major pathways.

Biological Effects

One measure of the impact of pollution on the marine environment is the effect on marine organisms. The effects of massive pollution are easily seen, and are not the object of IDOE sponsored research. Rather this investigation, initiated in 1973, is concerned with subtle effects on behavior and physiology which can have serious consequences on a long-term basis.

The emphasis is on open-ocean species; these are difficult to maintain in the laboratory and are generally more sensitive to pollutants. To assess pollution effects on open ocean organisms, and on the overall community structure in the ocean, IDOE is supplementing its laboratory studies with the Controlled Ecosystems Pollution Experiment (CEPEX), in which over 2 million liters of seawater and its included biota have been contained in large plastic enclosures. The effects of pollutants are then determined by perturbing one enclosure while maintaining another as a control.

The **Environmental Forecasting Program** aims at developing improved physical and mathematical models of the oceans and atmosphere. Its component projects are:

Mid-Ocean Dynamics Experiment (MODE)

MODE, initiated in 1971, is an investigation of the role of mesoscale eddies in the ocean circulation. It is jointly funded with ONR, and includes some NOAA participation. These mesoscale eddies are believed to contain at least as much kinetic energy as the mean ocean circulation, and possibly as much as ten times more. Where the energy comes from, how much is present, and what it does are questions which must be answered in order to refine the numerical models that are the basis of environmental prediction.

An observational program in a region south of Bermuda has yielded new techniques and devices for measuring mesoscale motions, a mass of data constituting a case history of the kinetics of a single eddy, a series of synoptic maps indicating the possible nature of the eddy field, and a preliminary estimate of the statistics characterizing the eddy field. MODE results are expected to provide guidance in the interpretation of historical or incomplete data from other regions, and to be of value in computer simulation of eddy motions.

MODE is now embarking on a new phase, called POLYMODE, which is jointly planned by the United States and the U.S.S.R. to follow up on many of the earlier measurements in MODE and in a similar Russian study called POLYGON, but on a larger scale in time and space, and in a different region of the Atlantic.

North Pacific Experiment (NORPAX)

NORPAX grew out of an ongoing study, funded by ONR, of the relation between areas of anomalous sea surface temperature in the North Pacific and anomalous weather and climate occurrences over North America. Taken on as an IDOE project in 1972, and jointly funded by ONR and IDOE, NORPAX is an investigation of long-period, large-scale ocean-atmosphere coupling, aimed at discovering how oceanic processes in the upper layers of the North Pacific relate to the weather and climate of the Pacific and the continents to the east.

One dramatic aspect of NORPAX has been the description of a pattern of large-scale oceanic and atmospheric anomalies which appear to be associated with *El Nino* [1] conditions, and which may

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[1] Under normal conditions, southeasterly winds blowing along the Peru coast drive the surface waters of the Peru Current away from shore, bringing about upwelling of cool, nutrient-rich waters from greater depths. These waters sustain sizeable bird and fish populations and support the Peruvian anchovy fishery, which is one of the

make it possible to predict the onset of an *El Nino*. Other accomplishments include the development of new measurement techniques, expansion of the existing data base, and the gathering of considerable data on ocean fronts.

Climate: Long-range Investigations, Mapping and Prediction

CLIMAP, begun in 1971, is an investigation of oceanic conditions during past ice ages. The primary data sources for the project are the deep sea core libraries of our oceanographic institutions. Fossil and geochemical evidence in these cores is used to infer past oceanographic conditions. Since these libraries contain samples from all areas of the world ocean, environmental charts for past ages can be constructed. Hopefully these will lead to better understanding of the role of the oceans in past climates.

Ocean surface conditions for the last ice age 18,000 years ago have been reconstructed on a global basis, and used as input to a numerical model to simulate the global climate at that time. In addition, detailed climatic sequences for the past 250,000 years have been reconstructed from a few cores representative of open ocean conditions.

International Southern Ocean Studies (ISOS)

ISOS, initiated in 1974, is a new project aimed at understanding the long-term, large-scale variability of dynamical processes in the Southern Ocean, which is believed to play a significant role in the ocean-atmosphere interactions that are so important to climate and climatic change. A second goal of ISOS is to provide background information that will be useful in assessing the biological productivity of the Southern Ocean, and its potential role in the storage and distribution of ocean pollutants.

The **Seabed Assessment Program** is directed toward better management of marine mineral exploration and exploitation. It consists of:

South Atlantic Margins

The continental margins are important economically. They contain rich deposits of heavy minerals, sand and gravel in their nearshore regions, and oil and gas further offshore. They also

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most productive in the world and is a major contributor to the world fishmeal supply. *El Nino* is the occasional disruption of this system which occurs when warm, nutrient-poor water spreads southward from the equator, displacing the cool, fertile water of the Peru Current, severely impacting the bird and fish population (and the anchovy harvest), and causing rain to fall on the parched Peruvian desert. Recently it has been found that *El Nino* is only the coastal manifestation of a much larger-scale process involving the entire system of equatorial currents in the Pacific.

provide clues relating to the processes of seafloor spreading which operated at the time of continental separation. Yet except in regions of extensive oil development, the continental margins of the world are largely unknown.

The continental margin studies, begun in 1971, have concentrated on the margins of the South Atlantic because these were among the least known. Comprehensive geophysical and geological data have been obtained in portions of the eastern Atlantic extending from South Africa to Portugal (completed in 1973), and along the coast of South America from its southern tip to the Caribbean (still underway). These studies are expected to provide insight into the processes of oil field formation during the early stages of seafloor spreading. They have also identified specific areas off the coasts of Africa and South America where the nature of the sediments indicate the possibility of substantial accumulations of oil and gas, sufficient to justify opening up these locations to oil exploration.

Metallogenesis and Plate Tectonics: The Mid-Atlantic Ridge and the Nazca Plate

Studies in mining areas suggest that metallic ores may have formed under conditions similar to those now operating along the mid-oceanic ridges and active trenches. To verify this, investigations into the relationship between metallogenesis and plate tectonics have been carried out along the Mid-Atlantic Ridge since 1972, and on the Nazca Plate since 1971.

In the French-American Mid-Ocean Undersea Study (FAMOUS), jointly funded with ONR and NOAA (and coordinated with NSF's Deep Sea Drilling Project), French and American scientists investigated processes along the Mid-Atlantic Ridge using manned submersible vehicles. Rock samples, sediments, and water collected during this effort suggest that metalbearing solutions are coming to the surface at selected points on the ridge valley and on the adjacent fracture zones.

Teams of geologists and geophysicists are making an intensive study of the processes operating along the edges of the Nazca Plate in the eastern South Pacific and their relationship to the extensive copper deposits in the Andes. These processes appear to carry metalliferous sediments under the Andes where they are concentrated into mineral deposits and subsequently uplifted and eroded to the point where they are available for exploitation. The project has found evidence of extensive faulting associated with accretion of sediments in the Peru-Chile Trench, and of metal-rich

sediments over extensive areas of the Bauer Basin, and has vastly increased the data base for the geology and geophysics of the Nazca Plate.

Manganese Nodules

Approximately 25% of the deep ocean floor is known to be covered by manganese nodules, aggregations of metals containing varying amounts of iron, manganese, copper, nickel and cobalt. This project, which started in 1972, has produced a series of maps showing the worldwide distribution of nodules by metallic content, with special emphasis on portions of the North Pacific where their economic potential seems greatest. These maps provide a firm base on which more detailed studies can be made. In addition, they have been used by delegates to the Law of the Sea Conference and other international groups concerned with the legal or ecological aspects of nodule exploitation. Other studies are underway on the environmental conditions under which nodules form and grow, their rate of growth, and changes over time.

The **Living Resources Program** is aimed at increased understanding of the oceanic processes affecting marine life. Its two projects are:

Coastal Upwelling Ecosystems Analysis (CUEA)

Coastal upwelling regions, in which wind-driven currents bring nutrient-rich waters from depths of tens or hundreds of meters to the surface, provide roughly half of the world's fish harvest, although they comprise only one percent of the total ocean area. Upwelling systems represent complex interactions between the atmosphere, the sea and the marine life it contains. Understanding these systems requires the combined effort of meteorologists and physical, chemical, and biological oceanographers. CUEA, which began in 1972, is an attempt to achieve sufficient understanding of upwelling ecosystems so that responses of these systems to change may be predicted from monitoring a few key biological, oceanographic, or meteorological parameters.

Field studies of the physical aspects of upwelling were carried out off the Oregon coast, and studies of the biological aspects off the coast of Baja California, in 1972 and 1973. A joint effort (JOINT I) was conducted off the coast of northwest Africa in 1974, and a study of upwelling in the *El Nino* region off Peru (JOINT II) begins in 1975. (The African study involved substantial international participation, and in the Peruvian study the South American nations are conducting the major portion of the work.) These field studies aim toward development of a general upwelling eco-

system model which will link physical inputs, geographical setting, and biological productivity, with emphasis on exchanges of energy and nutrients between the physical and biological components of the system.

Seagrass Ecosystem Study (SES)

Seagrass meadows are found in shallow water along the nearshore areas of every ocean except those in polar regions, and play a major role in the ecology of coastal waters. They are among the most productive systems in the ocean, and they play a significant role in stabilizing coastal sediments, yet relatively little is known about them. SES, which began in 1974, includes studies of the contribution of seagrass ecosystems to other food webs, especially those of direct importance to people, studies of the global distribution of seagrasses, and studies of their life cycles, their environmental tolerance limits, and their suitability for transplantation.

International Aspects

There is some degree of international involvement in all of the above projects; this takes a variety of forms and it is hard to say what is "typical". All projects have one or more scientists from other nations participating; more extensive involvement of foreign governments and institutions is difficult to quantify due to different methods used in categorizing expenditures. CEPEX is being carried out at a field site in Canada with the participation of a few Canadian scientists, and the British are setting up a similar experiment on a smaller scale in Scottish waters, but the project is fundamentally a U.S. funded and planned activity. POLYMODE, on the other hand, is a jointly planned, funded and managed program of the United States and the U.S.S.R. CUEA's JOINT I field program off the west coast of Africa in 1974 saw France, Spain, Mauretania and West Germany contributing more total ship time than the U.S.; JOINT II, a study of coastal upwelling off the coast of Peru which begins this year, is a cooperative effort of the United States and the nations on the west coast of South America, with the latter doing the major portion of the work. The Seagrass Ecosystem Study is integrated with projects of other nations through an international committee representing the United States, Denmark, France, Japan and the Netherlands. The Federal Republic of Germany, France, the United Kingdom, India, Italy and Japan all participated in GEOSECS with ships, personnel and laboratory facilities. Participants from fifteen other nations joined with the U.S. in carrying out the Eastern South Atlantic Continental Margins Survey, and Argentina and Brazil have been full partners with the U.S. in the study of Southwest Atlantic Margins. CLIMAP has provided an opportunity to integrate related work carried

Table 2. Participation By Other Nations in U.S.-Led IDOE Programs
1973-1974

	GEOSECS	MODE	NORPAX	CLIMAP	SE ATLANTIC MARGINS	NAZCA PLATE	MID-ATLANTIC RIDGE	MANGANESE NODULES	CUEA	SW ATLANTIC MARGINS	POLLUTANT TRANSFER	CEPEX
Argentina					•					•		
Australia			•									
Belgium	•											
Bolivia						•						
Brazil					•					•		
Canada	•		•				•		•			•
Chile						•						
China, Republic of			•		•							
Colombia						•						
Denmark				•								
Ecuador			•			•						
France	•	•	•	•	•		•	•	•			
Germany, Dem. Rep. of									•			
Germany, Fed. Rep. of	•	•	•	•	•			•	•			
Ghana					•				•			
Guatemala					•							
Iceland							•					
India	•											
Israel					•							
Italy	•											
Jamaica					•							
Japan	•		•	•				•				
Mauritania									•			
Morocco									•			
Netherlands				•								
New Zealand			•					•				
Norway				•					•			
Peru						•						
Portugal					•		•					
Senegal					•				•			
Spain					•				•			
Sweden		•										
Switzerland				•								
Union of South Africa					•							
United Kingdom	•	•	•	•	•		•		•		•	•
U.S.S.R.		•										

Table 3. Participation By Nations in IDOE Programs Initiated By Nations Other Than the U.S. 1973-1974

	S.W. Atlantic-Subtropical Convergence Study [1]	Western Pacific-Equatorial Undercurrent Study	Southwest Pacific-Ships of Opportunity Experiment	S.W. Pacific/Eastern Indian Ocean-Sea Surface Current Program	Overflow (International Council for the Exploration of the Sea, Regional Program)	Joint Air-Sea Interaction Program (JASIN)	Joint North Sea Wave Project (JONSWAP)	El Nino Investigation	Arabian Sea Monsoon Circulation Experiment (MONEX) [1]	GATE Oceanographic Program	Pollution/Ecology Studies of the Hallifax-Bermuda Section	Saronikos Gulf Pollution Study	East & Southeast Asia Tectonic Development Study	North Atlantic Seismic Project (NASP)
Argentina	•													
Australia		•	•	•						•				
Brazil										•				
Canada					•		•			•	•			
Chile								•						
Colombia								•		•				
Denmark					•		•							
Ecuador								•						
France		•	•	•	•					•				
Germany, Fed. Rep. of					•		•			•	•			
Greece												•		
Iceland					•									
Indonesia													•	
Japan			•										•	
Khmer Republic													•	
Korea, Rep. of													•	
Malaysia													•	
Mexico										•				
Netherlands						•	•			•				
New Zealand			•											
Norway					•									
Peru								•						
Philippines													•	
Portugal										•				
Thailand													•	
United Kingdom					•	•	•			•	•			•
United States				•	•	•	•			•	•	•		•
USSR					•				•	•				•
Venezuela										•				
Viet-Nam, Rep. of													•	

[1] These two projects have been initiated by the countries indicated. In both cases the countries have indicated that they expect to develop substantial international participation in the very near future.

on by scientists all over the world funded by their own nations. FAMOUS was a bilateral French-American effort; however each country carried out its own portion of the field work and data analysis separately. New Zealand and West Germany, between them, have provided more than half the ship time for the Manganese Nodules project. In the forthcoming study of metallogenesis in Southeast Asia, the local nations will be responsible for a significant portion of the land and coastal water aspects, while the United States does the deep sea work.

Tables 2 and 3 summarize the status of international participation in IDOE projects of the U.S. and other nations, as of 1974.

In addition to the U.S. projects described above, the IDOE has sponsored international workshops concerned with metallogenesis in Southeast Asia, geology and geophysics of the Caribbean, and physical and biological aspects of *El Nino,* as precursors to the development of truly international projects in these areas.

Several factors contributed to the slow growth, initially, of international participation in the IDOE. One is that the IDOE concept originated in the United States, and U.S. scientists were ready to get started as soon as funds were available; there was a time lag before other nations reached a corresponding state of readiness. Even so, during the first year or two, while the direction of the U.S. program was unsettled, it was unclear to other nations (and to many American scientists as well) just what was there for them to participate in. As the nature of the program became clear, other nations began to participate in ongoing projects on an individual scientist basis while seeking to generate willingness to provide funds on the part of their own governments.

A second factor contributing to the slow start of international collaboration was the tendency for U.S. scientists to do all of the planning themselves, and to keep the most essential elements of a project under their own control. Other nations were welcome to carry on parallel studies that added to the overall value of the project. This attitude has gradually changed, and today other nations contribute equally with the United States from the outset in planning new projects.

A third contributing factor has been the relatively low funding level of the U.S. program, and the fact that it was viewed primarily as a U.S. scientific effort, not a foreign aid program. This meant that the IDOE could not become truly international with U.S. funds alone, but required funding on a comparable level from other governments. This is now beginning to take place at an increasing pace.

Program Management

Generally speaking, the prime criteria by which a potential IDOE project is judged appear to be:

- It must be scientifically sound;
- It must address a problem which relates to the overall goal of acquiring the understanding needed to better utilize the oceans and their resources, and which falls within one of the four IDOE program areas;
- It must not duplicate programs that are the responsibility of a Federal mission agency or which are actively pursued by some other segment of the oceanographic community, either government or private;
- It must attack this problem in an integrated, comprehensive manner, and be built of components which in the aggregate promise to provide a broader insight into phenomena, processes and relationships than presently exists.

Very often, but not always, projects meeting these criteria have been expensive (on the order of $0.5 to $3.0 million per year), long-term (four to ten years), and multidisciplinary, involving scientists and facilities of several institutions including some in other nations. Initially an effort was made to support research carried out by other government agencies and by industry, as well as in universities, but in recent years virtually the entire effort has been carried out by academic oceanographic institutions.

There is no rigid system for initiation, selection and management of IDOE projects. Each is dealt with in an *ad hoc* manner depending on the nature of the problem addressed and the scientific approach adopted. However certain common features are apparent, and to the extent that there is a "typical" approach, it is essentially this:

The ideas for IDOE projects emerge from the scientific community, not from the National Science Foundation. Typically, a small group of individual scientists make informal contact with the IDOE Office, suggesting a certain topic and identifying, in broad general terms, various aspects of the problem and methods of attack. If the subject seems promising, this will be followed by an informal and then a formal proposal which may ultimately result in a planning grant on the order of some tens of thousands of dollars. Activities under this planning grant may include a literature search and, generally, a workshop, to which a substantial number of scientists in relevant specialties are invited. The workshop produces a report which analyzes the nature of the problem, assesses its importance and relevance to ocean utilization, identifies the extent to which a scientific and technological capability for attacking it exists, and suggests possible research strategies. On the basis of this report, a scientific planning committee of five to ten scientists may be selected and charged with formulating a project proposal. This preliminary process may take about a year.

When the project proposal is received by the IDOE Office, it is sent out for mail peer review by anywhere from two to ten referees. The peer reviews are collated and summarized by the program manager, and the package presented to the IDOE Proposal Review Panel which meets three or four times a year. The Panel consists of eight members from various disciplines, so that all aspects of the IDOE program are represented. Panelists are generally familiar with many of the leading members of the U.S. oceanographic community, including those who are called on to serve as referees and, often, those who are identified as principal investigators, as well as with the facilities and capabilities of the various oceanographic institutions. This is significant, for Panel debate often centers not so much on the scientific validity of the proposal as on the ability of the identified researchers and institutions to implement it; prime points of discussion often concern the availability of needed facilities and technical support and the extent to which inter-institutional cooperation is adequately provided for. If the panel gives its approval, the funding decision is left up to the IDOE Office, where it is made on the basis of available funds and the relative priority of various approved proposals.

Once the process of preparing a formal project proposal is underway, the planning committee works closely with the program manager in putting together an appropriate management structure. Here again every project is different. As a general rule, two or more major institutions, and additional individual scientists from other institutions, are likely to be involved. Projects of this sort cannot be managed in the same way as the typical "small" project supported by NSF's Research Directorate,[1] involving one principal investigator, one or two post-doctoral associates, and one or two graduate students. (A major IDOE project may involve twenty or more principal investigators from ten or more institutions, with attendant graduate students, technicians, etc.) When IDOE began there existed little in the way of management models for such efforts. One exception is NSF's Deep Sea Drilling Project which is managed by the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES), a scientific planning body consisting of eleven institutions in four countries, with the Scripps Institution of Oceanography serving as prime contractor.

The management apparatus that has evolved centers, typically, on a scientific council consisting of all the principal investigators working on the project. This council may, as appropriate, be subdivided into committees or panels dealing with distinct aspects of the project (e.g., a theoretical panel, a statistical panel, a committee on ship needs, etc.). There is a steering committee or executive committee consisting of from three to ten members of the council; this group provides continuing

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[1] See footnote on page 7.

guidance and direction to the project. There is usually an overall chairman or co-chairman, a scientific coordinator, executive officer, or project manager, and sometimes a small administrative staff. New proposals for incorporation into the project are considered by the scientific council before being forwarded to the IDOE Office, thus ensuring that all proposals are indeed integrated into the overall plan.

This apparatus takes somewhat different form in different projects, and works more effectively in some than in others. When difficulties arise, the IDOE Office may assist in establishing a special advisory group to recommend solutions. Project accomplishments are reviewed every one or two years. There is no guarantee that the project will be funded for its full four to ten year anticipated lifetime, although there is obviously a serious commitment on the part of the scientists and the Foundation to keep the project going as long as the work being carried out continues to be sound and promising.

In addition to the work of the Proposal Review Panel, the IDOE program as a whole receives periodic overview from NSF's IDOE Advisory Panel and from the National Academy of Sciences and National Academy of Engineering, as well as from the National Science Board. Thus the entire IDOE program, from project inception to completion, has a firm base in the American scientific community, and leans heavily on that community for ideas, criticism and guidance.

Appendix 3. Request from the Director, NSF, for Review of the IDOE by NACOA.

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE DIRECTOR

FEB. 19 1974

Dr. William Nierenberg, Chairman
National Advisory Committee on Oceans and Atmosphere
Department of Commerce
Washington, D.C.

Dear Bill:

As you know, the International Decade of Ocean Exploration (IDOE) is approaching its fifth year as an NSF program. I believe that this half-way point is an appropriate time to review the status of the IDOE and to consider its future. For example, what should be done about those projects which might be productively extended beyond the nominal 10-year life of the program? Should the IDOE be extended beyond 1980 or should these projects be transferred to other programs? Extension of the IDOE beyond its currently planned termination date requires a clear rationale and description of program content.

NACOA has the disinterested perspective needed to review the scientific, budgetary, and managerial aspects of the program, and more generally, IDOE's compatibility with national priorities in marine and atmospheric sciences. I would like to ask NACOA's assistance in conducting such a review with the evaluation and recommendations for the future of the

IDOE available to me by the summer of 1975. Among the issues that require study are:

(1) The responsiveness of IDOE to the 1969 guidelines under which it was established.

(2) The current validity of the guidelines as valid expressions of national and international needs in marine science.

(3) The effectiveness of large, directed research projects in addressing the problems posed by the original guidelines.

(4) Have IDOE findings to date been of high scientific quality and have these contributed to national and international social, economic, and political objectives?

(5) Given the nominal termination date of 1980, what recommendations would NACOA make about the future of the IDOE?

These topics by no means exhaust the kinds of questions that should be asked, but do give some indication of their scope and flavor.

Should NACOA be willing to conduct this review, I will be happy to detail an NSF staff member to NACOA to assist with it. I am also prepared to make available limited funds for specialized workshops and consultants.

Sincerely yours,

/s/ Guy

H. Guyford Stever
Director